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11. Innovation in the Global Economy

For most people it comes as a surprise that almost half of United States patents are issued to foreign inventors. In this chapter we turn to why that might make sense, and what we get in return. It is not only the United States that grants patents to foreigners. All major jurisdictions do this, and not just patents. Almost all intellectual property available to domestic inventors is also available to foreign inventors. This is true in most countries.

The most important patenting jurisdictions are Japan, the European Union, and the United States, whose patent o±ces are respectively the JPO, the EPO, and the USPTO.[1] Collectively, the residents of these three jurisdictions account for only about 13 percent of the world population, and no more than half of the world GDP.[2] Even more disproportionate is the fraction of total patents accounted for by inventors in these jurisdictions. Instead of 13 percent or even half, as we might expect if the countries of the world were symmetric in their innovative capacity, in 2002 inventors from the trilateral block collectively applied for 97 percent, 94 percent and 88 percent of patents in the JPO, EPO and the USPTO respectively (EPO, JPO, and USPTO 2002).

[1] The European Patent O±ce is a separate body from the European Union, and has no authority to issue patents. It examines patent applications which are then issued (or not) by the member countries. The E.U. and the European Patent Convention are not entirely overlapping.

[2] Because of the problem of purchasing power parity, it is di±cult to compare GDP in the industrialized world with GDP elsewhere. See Heston, Summers, and Aten 2002 for GDP estimates that account for purchasing-power parity. The relative GDPs of Japan, the European Union (including 15 nations in 2002), and the United States are about 18:36:46. The relative populations are about 16:47:37 (European Union in the U.S. 2003).

Even though all inventors have the same patent rights in each jurisdiction, regardless of their own nationalities, it is not true that the three patent offices issue patents proportionately to, say, GDP or population. Patents are not issued in proportions of 16 percent, 47 percent, and 37 percent in any of the three patent offices, as would reflect relative populations. They deviate in two ways: there is a home bias, and Japanese inventors patent at a disproportionately high rate. In 2002, the USPTO granted 52 percent of its patents to American inventors and only 48 percent to foreign inventors, disproportionately to Japanese. The home bias in the JPO is even greater. The JPO issued 90 percent to Japanese inventors, with 5 percent to Americans and 4 percent to Europeans. The EPO issued 54 percent to European inventors, 25 percent to United States residents, and 17 percent to Japanese (EPO, JPO, and USPTO 2002).

One reason for the home bias might be that innovations in each country are targeted at the domestic market. The Japanese bias might additionally arise from a historical difference between patent systems. Recall that United States and European patents can have many claims. Until a reform in 1988, this was not true in the Japanese system, where there was a single claim per patent. After the reform, the number of claims per patent increased up to fourfold, depending on technology field (see Branstetter and Sakakibara 2001).

For copyrights, there are no administrative data analogous to those available for patents, so it is hard to track the international dimension. This is because there is no application or examination process. Even notification with the symbol © is no longer necessary. To a large extent, international copyrights are automatic, although they might not be enforced.

This chapter turns to how the globalized system arose, why globalization does or does not make sense, and the extent to which it encourages countries to rely on intellectual property incentives instead of, for example, public sponsorship.

11.1. Trade Policy and Treaties

The reciprocal exchange of intellectual property rights is governed by treaties. The earliest large-scale intellectual property treaties were the 1883 Paris Convention on patents and other industrial property, and the 1886 Berne Convention for literary and artistic works. These treaties began with only a

few members. Under various revisions, they have remained in e®ect ever since, and now have well over 100 members. Both established the principle of \national treatment of foreign inventors." National treatment is the provision by which national intellectual property rights must be extended to foreign inventors. Within each member country, foreign inventors receive the same rights given to nationals.

The most important modern descendant of the Berne and Paris Conventions is the 1994 agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS), which has over 140 members. Membership in TRIPS is required for membership in the World Trade Organization. The WTO, which governs more than 97 percent of trade, creates trade advantages for its members, binds them to certain limitations on trade tari®s, and creates and enforces obligations to provide certain intellectual property rights. There are important nations that have not yet become part of these treaties, including the former Soviet states.

The principle of national treatment does not specify what subject matters should be protected, but only speci¯es that whatever protections are given to domestic inventors shall also be extended to inventors in other member states. TRIPS goes beyond the principle of national treatment by also specifying a minimum set of rights that each member state must provide. Until the TRIPS agreement, there were sharp di®erences in what was protected { for example, many countries did not protect pharmaceuticals.

The trilateral markets are the important markets in which to receive intellectual property rights, mainly because they are large. An inventor in, say, South Korea will ¯nd it more pro¯table to receive intellectual property rights in any or all of those three markets than to protect the intellectual property at home, at least for inventions that are globally useful. In fact, if inventors in a small country like South Korea can be protected in the United States, Europe, and Japan, it is hard to see why the small country would grant domestic intellectual property rights at all. Why not use the three large markets to reward their inventors, without imposing proprietary prices on their own consumers? Inventors and consumers in the large markets would naturally take a dim view of such free riding, and TRIPS forbids it.

The United States stance toward free riding has changed with its economic circumstances. In the early days when the United States was a small, underdeveloped country, it allowed its nascent printing industry to reproduce British books without paying royalties. Printers did not give up

this privilege even after 1789, when the Constitution authorized the federal government to grant intellectual property rights. The federal copyright statute enacted in 1790 in response to lobbying by American authors, especially Noah Webster, provided no protection for foreign authors.

In the next century, the United States refused to join the Berne Convention, which granted reciprocal copyright privileges among all the member states. The official reason was that the United States had different procedures concerning registration and copyright notice, and did not want to conform to world practice. However, this had other benefits as well. Skeptics will notice that United States readers continued to dodge royalties on foreign works.

It was not until American authors became popular overseas that they began to favor an agreement with England for reciprocal copyright privileges. Such an agreement was made in 1890 after the publishing houses, seeing a profit opportunity, joined their effort. Although the United States did not join the Berne Convention until 1989, it was a party to other copyright treaties earlier (Beldon and Sampliner 1996-1997; Ryan 1998, 52).

The problem of international piracy has become more acute in the digital age, and American interests have reversed. There is still a copyright conflict between developing countries and developed countries, but now the United States is a developed country that wants to protect its interests. Today, copyright piracy usually concerns software, movies and music on disk, and to some extent textbooks. As soon as the popular Harry Potter movies were released, illicit copies were reportedly selling on the streets of Beijing, even before they had reached most British and American movie houses. These acts of piracy are not a formal government policy against protecting foreign authors, but they have the same effect.

The globalization of intellectual property rights is also tied to trade policy more generally. In the United States, trade policy is governed by the 1974 Trade Act. Among other things, it authorizes the United States Trade Representative (USTR) to investigate unfair trade practices and impose trade sanctions on the perpetrators. In 1984, section 301 was amended to say that a failure to protect intellectual property is an unfair practice. This strengthened United States copyright and patent lobbies, by giving them a weapon to pressure foreign governments for stronger intellectual property protection without a cumbersome appeal to the international bodies that enforce treaties.

A second amendment, enacted in 1988, is equally important. It requires the USTR to produce an annual assessment of piracy, and to announce a list of priority objectives for trade diplomacy that targets speci¯c countries. The process requires the USTR to accept public comment, which gives the intellectual property lobby an automatic platform. They routinely produce \white papers" that the USTR is obligated to read and consider.

An umbrella lobby organization on copyright matters is the International Intellectual Property Alliance (IIPA), which represents various member organizations on behalf of movie, music, and software producers. In the 1980s they produced an estimate of piracy losses that jolted policymakers { $1.3 billion { and that precipitated a round of ¯erce negotiations with certain targeted countries, in particular, South Korea and China (Ryan 1998, chap. 4). More recently, the Business Software Alliance (2001) reported that the piracy rate is 37 percent of total usage of business software in the world as a whole, with country-speci¯c rates as high as 94 percent in China. Similarly, the International Federation of the Phonographic Industry (IFPI), a lobby organization that collects data on music piracy, estimates that piracy reduces legitimate sales of music CDs by 22.7 percent.

These numbers make for powerful rhetoric, especially when translated into dollar losses. However, it is obviously naive to estimate lost revenue by assuming that each pirated copy would otherwise have been bought at the list price. Although pirated copies probably crowd out some sales, the crowding out is presumably not one to one. In fact, Hui and Png (2003) estimated that piracy reduces sales by only 6.6 percent worldwide, assuming that industry prices are ¯xed. This is still substantial, but much less than the loss estimated by industry.

Perhaps the greatest victory of the copyright and patent lobby was to inject intellectual property into the negotiations over the General Agreement on Trade and Tari®s (GATT) in the early 1990s.[3] This was the origin of TRIPS. Going beyond the earlier treaties that established the principle of national treatment, TRIPS established standards of protection that all members must adhere to, including lengths of protection and requirements that certain subject matters must be protected. Such an e®ort is generally called harmonization. For example, TRIPS mandates protections for

[3]GATT is a multilateral trade agreement that dates back to the mid-twentieth century. Its objective is to avoid mutually destructive trade restrictions and tari®s that might otherwise arise as countries try to protect their own manufacturers. The rules of trade change in rounds of negotiation, the most recent of which was the Uruguay Round.

pharmaceuticals, some bioengineered products, computer chips, and computer software. Disputes about whether members of the treaty are in compliance can be brought to the World Trade Organization, which is the successor to GATT, and is also a dispute-resolution body for the rules negotiated in TRIPS.[4]

In addition to TRIPS and other treaties that govern the treatment of foreign inventors and the substance of intellectual property law, there are treaties that coordinate the administrative aspects of running the intellectual property system. It can be expensive for inventors to exercise their worldwide intellectual property rights. For patents, the legal fees and translation costs for an individual application can cost thousands of dollars per country. To avoid this, many countries have uni¯ed their application procedures. The Patent Cooperation Treaty of 1970 (amended in 1979 and 1984) provides a uni¯ed application procedure for 115 countries, with an optional preliminary examination that gives the applicant some con¯dence that individual countries will approve the application. After the PCT examination is complete, the applicant can route the application to various member countries, with patents issuing according to national laws.

Further coordination for the European community is provided by the 1973 European Patent Convention, which established the European Patent O±ce. The EPO conducts examinations and issues patents that are interpreted according to the individual laws of the twenty states in which they apply (mostly overlapping with the European Union). An inventor who only seeks protection in Europe can apply directly to the EPO, or can ¯le a PCT patent, which is then routed to the EPO.

The objective of this chapter is to contemplate the economic forces behind and consequences of intellectual property treaties. As already mentioned, national treatment of foreign inventors creates an opportunity for free riding. This can be cured to some extent by harmonizing protections, but many commentators think that the harmonizations of TRIPS went too far.

Given the strength of the intellectual property lobbies in the United States (Ryan 1998), some commentators believe that the USTR was \captured" by them in the TRIPS negotiations and ended up negotiating on their behalf. However, not all domestic interests are aligned with that lobby. User groups such as the Association of Research Libraries generally prefer low

[4] See Samuelson 1999 for the history of dispute resolution and the policy issues involved.

prices and free access, whether the protected property is o®ered by domestic or foreign vendors.

In view of these con°icting interests, what type of intellectual property policies should be viewed as optimal? That is the subject of the next subsection. Is there any sense in which we can infer that the copyright and patent lobbies have overturned the interests of the developed world as a whole? What is the likely consequence of a harmonization e®ort in which the members of TRIPS negotiate common minimum protections? Would we expect harmonized protections to be stronger than those that would arise if countries chose their policies independently?

11.2. National Treatment and E±cient Protection

Before discussing national treatment further, we introduce the simple model used in the remainder of the chapter. The simple model focuses on product innovations, and we use it to study the policies that best mitigate global deadweight loss while supporting innovation. We then investigate the policies likely to arise in equilibrium among countries, with and without a harmonization e®ort.

Suppose there are two countries, a, w. The focus will generally be on country a, and w will be interpreted as \the rest of the world." For each of $i = a, w,$ assume for simplicity that the market for each new commodity is the same within each country, generating consumers' surplus v^a and v^w when sold at the competitive price. If country w is larger than country a, it is natural to assume that v^w is larger than v^a. Assume, as we did for computer software, that the marginal cost of producing the new commodity is zero.

If an innovation is sold by a monopolist, we can think of v^a (similarly, v^w) as divided into three parts: the consumers' surplus that is available under monopoly, mv^a, the pro¯t, πv^a, and the deadweight loss ℓv^a (see ¯gure 2.2), where $m + \pi + \ell = 1$. Pro¯t and consumers' surplus are assumed to be the same under national treatment whether the innovation is supplied domestically or by a foreign ¯rm.

If inventors in country a can protect their inventions in country w as well as country a, then their per-period pro¯t is $\pi(v^a + v^w)$ instead of πv^a. In fact, with bilateral protection, inventors in both countries receive $\pi(v^a + v^w)$. This observation has an important consequence: under a system of national

treatment, an inventor's incentives to invent do not depend on where he or she is domiciled, regardless of differences in intellectual property laws – inventors in both countries receive $\pi(v^a + v^w)$. Hence, there are good reasons to think that the efficacy of intellectual property protection cannot be studied by comparing the success of inventors across countries with different systems. Even if there is heterogeneity in intellectual property protections, there is no heterogeneity in firms' incentives.

Inventors in both countries confer externalities on foreign consumers whether or not they receive foreign patent rights, although in different amounts. If an invention in country a is not protected in country w, then it can be supplied competitively in w, generating per-period consumers' surplus v^w. This is what we previously called free riding. If the invention is protected in w, then some consumers' surplus is repatriated to country a as profit in amount πv^w per period. The per-period external benefit to w is then mv^w rather than v^w, reflecting the outflow of profit and deadweight loss.

From country a's perspective, protection in w is unambiguously desirable. Protection allows country a to repatriate some of the external benefit conferred by its inventors. The fact that this imposes a loss on residents of w is of no concern to policymakers in a. However, although it is easy to see why country a would want protection in w, it is not theirs for the taking. Why would policymakers in country w grant national treatment to innovators in a? Wouldn't they be better off free riding?

Indeed they may. Some commentators think that the United States took this view at the founding of the republic, when they decided to protect national authors but not foreign authors. In more recent controversies, Ryan (1998, 80-81) describes how the desire to free ride has sometimes been explicit. In particular, China has argued that local printing and reproduction of Western works provides local jobs as well as cheap access to knowledge, and is therefore an aid to development. Western negotiators have countered that the actual printing or reproduction effort would take place in the developing countries in any case, since that is more efficient, and that copyright holders would not charge the same high royalties that they charge in the West. This may be true, but there is still an advantage to avoiding royalties.

If small or underdeveloped countries do not have inventions that they wish to protect in the large markets, then the large, innovative countries have little leverage to overcome the incentive to free ride. In the GATT negotiations, the incentive to free ride was overcome by linking trading

privileges to membership in TRIPS.

We wish to understand the e±ciency properties of the intellectual property regime that is likely to arise under national treatment, and also under a harmonization e®ort. We start by exploring how aggregate deadweight loss depends on lengths of protection in the two countries. Here we will consider two policy variables jointly: the geographic extent of protection, and the length of protection. Of course, when copyright holders or other rightholders ask for a geographic expansion of their rights, they generally do not volunteer for a simultaneous reduction in how long they are protected. The point here is to reason from a global e±ciency point of view. Assuming that the goal is to keep the incentives for invention (pro¯t) ¯xed, is it better to provide geographically expansive rights for a relatively short time, or to provide geographically restricted rights for a longer period?

Perhaps surprisingly, the answer is that the geographic extent of protection does not a®ect aggregate deadweight loss, provided the length of protection is tailored to keep the incentives for invention ¯xed. This conclusion depends only on the assumption that the ratio of pro¯t to deadweight loss is the same in both markets, regardless of the relative sizes of the markets. It is another application of the ratio test discussed in chapter 4.

Let T_a, T_w represent the (discounted) lengths of protection in a and w respectively. The total pro¯t that accrues to an inventor by marketing the proprietary product in both a and w is $\pi(v^a T_a + v^w T_w) = ¦$. The accompanying deadweight loss is $\ell(v^a T_a + v^w T_w)$. Thus, all combinations (T_a, T_w) that provide the same total pro¯t ¦ also provide the same total deadweight loss, namely, $\ell\ ¦/\pi$.

As a consequence, to a ¯rst approximation, the controversies over how to protect intellectual property in the international arena are largely about equity or fairness, and not about e±ciency in the sense of aggregate deadweight loss. The following three regimes are equally e±cient in the sense of generating the same aggregate deadweight loss, provided that patent lives are adjusted so that an inventor's pro¯t is always the same:

1. Inventors are protected only in their own domestic countries (autarky),
2. Inventors are protected in all countries, regardless of domicile,
3. Inventors everywhere in the world are protected in one country, which for most inventors is not their own.

Autarky means that each country protects its own innovators and no others. This was the situation prior to the Paris and Berne Conventions. Under autarky, the inventions of each country become available for competitive supply in other countries { there are huge externalities from innovative countries to foreigners.

Is there anything wrong with this? One possible problem is that there is a limit to how much pro¯t can be collected from a small, domestic market. The maximum pro¯t in market a is $(1/r)\pi v^a$, which is the discounted sum of pro¯t if the pro¯t stream πv^a lasts forever. If v^a is small, such pro¯t may not cover the cost of innovations. Thus, if the world consists of many small nations, an autarkic system of domestic rights will not support very much innovation. In fact, however, the world as we know it has large jurisdictions like Japan, the United States, and Europe. In these jurisdictions, autarky is less likely to sti°e innovation.

Autarkic protection would seem the natural solution to the international equity/e±ciency problem, at least if regional markets are more or less the same size. Under a system of autarkic protections, the externalities that °ow among nations are more or less commensurate, and no country should feel less favorably treated than any other country. American inventors may complain that Japanese users do not help pay the cost of American inventions (and vice versa), but American consumers should also be pleased to receive Japanese inventions at competitive prices (and vice versa). The externalities balance out.

Oddly, however, this system of reciprocal externalities is precisely what is excluded by the principle of national treatment. Under a regime of national treatment, an invention that is protected for a domestic inventor must also be protected for a foreign inventor. Autarky is not possible.

Current practice follows the second option for inventions covered by TRIPS. However, it follows the third for certain inventions that are still only protected in a handful of high-protection countries like the United States.

The third option also prevailed prior to TRIPS, when the United States protected several types of knowledge that were not, for the most part, protected elsewhere, even in other developed countries. For example, computer software was protected by copyright in the United States, and the PTO was beginning to patent it, but those protections were either not provided or still being debated elsewhere. Many jurisdictions had no

protections for computer chips. For pharmaceuticals, many nations had no protections or only weak protections, undermined by compulsory licensing. The status of bioengineered organisms was similarly asymmetric. Starting in 1980, bioengineered organisms were protectable in the United States, but not in most jurisdictions abroad.

Thus, under national treatment, the cost of developing computer software, computer chips, and bioengineered organisms was largely borne by American users and users in other high-protection jurisdictions, whether the developers were domestic or foreign. Consumers and other users in low-protection jurisdictions could receive the bene¯t of competitive supply without paying to develop the innovations. The harmonization in TRIPS changed that. For example, it extends protection to biologically modi¯ed microorganisms, although it stops short of requiring protection for larger organisms like the Harvard oncomouse.

One might have thought on this basis that harmonization would bene¯t consumers in high-protection jurisdictions by spreading development costs around the world. However, domestic consumers would only have bene¯ted, at least in the short run, if the protection had been shortened. This was never on the table. Instead, the patent and copyright interests sought a geographic expansion without shortening the duration of rights.

From an e±ciency point of view, increased innovation might justify the expansion in rights. Indeed, the copyright and patent lobbies did not make their argument purely on grounds of fairness. They also argued that widespread piracy undermined incentives for R&D. This is true almost by de¯nition, but it does not mean that more incentives are necessarily better. As discussed in chapter 4, higher pro¯t might only lead to wasteful rent seeking.

11.3. Country-Level Optimal Protection

In an environment of national treatment, intellectual property rights are no longer just a way to encourage domestic invention. They also become a strategic instrument to a®ect pro¯t °ows among nations. To a®ect pro¯t °ows favorably, each country wants the strongest possible protections in foreign countries, and the weakest possible protections for foreigners in its own domestic market. Holding the total pro¯t $\pi(v^a T_a + v^w T_w)$ ¯xed, country a prefers $T_a = 0$ and a very large T_w, at least if country w is large enough to

support innovation. Deadweight loss to consumers in country a is $\ell v^a T_a$, which obviously increases with T_a. Similarly, deadweight loss increases with T_w in country w.

Previous chapters of this book have discussed e±ciency in the sense of aggregating all the costs and bene¯ts of both producers and consumers into a single measure, ignoring the con°icts of interest that can arise between them. Even in a domestic economy, this approach is not entirely defensible. The best justi¯cation is that consumers and shareholders are largely the same people. On average, a higher level of consumers' surplus and pro¯t will bene¯t everyone.

The argument for aggregating costs and bene¯ts is much weaker in the global economy. For that reason, we modify the premise, and assume that domestic policymakers only care about domestic consumers' surplus and pro¯t, net of domestic R&D costs. Thus we continue to assume that there are no irresolvable con°icts of interest within domestic borders, but that there are con°icts of interest across borders.

Instead of thinking solely in terms of optimality, we now think in terms of equilibrium. In equilibrium, each country chooses its intellectual property policy optimally for domestic consumers and producers, conditional on what the other country chooses. We ¯rst investigate the length of protection that each country would choose independently, and then consider the length of harmonized protection that each country would advocate if it believed that it could impose its choice on both countries.

The equilibrium with independent choices (T_a, T_w) has the property that T_a is optimal for country a conditional on the protection T_w in the other country, and vice versa.

To investigate this equilibrium, we make some preliminary observations. Suppose ¯rst that all innovations require the same R&D investment cost c. If T_w is long enough so that it covers the cost of innovations, $\pi v^w T_w \geq c$, then country a will not provide any intellectual property rights at all, $T_a = 0$. For country a it is better to rely on protection in country w, and allow its own consumers to bene¯t from competitive supply rather than proprietary prices. On the other hand, if the protection abroad is not su±cient to cover the costs of innovation, $\pi v^w T_w < c$, then country a will provide the complementary patent life required to cover the cost { that is, T_a such that $\pi(v^w T_w + v^a T_a) = c$, but no more.

Notice that any combination (T_a, T_w) will be an equilibrium if $\pi(v^w T_w + v^a T_a) = c$. If, for historical reasons, country w has strong (lengthy) protections, then country a can exploit that fact by granting lower protections. And of course each country is in the best possible position if it can rely on the other country entirely. The particular combination of protections that arises can easily be a matter of historical accident, and the initial historical accidents can perpetuate inequities.

We now expand the discussion by introducing "one-size-fits-all" intellectual property rights. Countries cannot set different patent lives or copyright durations for different pieces of knowledge. Patents have uniform length, regardless of how much the invention costs to develop. This aspect implies that countries will find it optimal to set lengths of protection so that it is not cost-effective to invest in all potential innovations.

In the domestic context, the Nordhaus trade-off discussed in chapter 4 was that it is only optimal to lengthen the intellectual property right if the value of the increased innovation outweighs the additional deadweight loss on innovations that would occur even with the shorter intellectual property right. The trade-off is between the marginal gains to innovation and the inframarginal losses due to deadweight loss on innovations that would occur in any case.

In the international context, there is another consideration. When a country lengthens its intellectual property rights, it generates an outflow of profit to foreign inventors. The increase in innovation must be balanced against the increased domestic deadweight loss and the outflow of profit, not only on the newly engendered innovations but also on all the innovations that would have occurred in any case. The consequence is that countries choose lengths of protection that are shorter than the lengths that maximize aggregated global consumer welfare, and shorter (as we will see) than the lengths they would harmonize on. They do this to stem the outflow of profit.

We will now see more formally why the countries choose protections that are too short. Let $\hat{c}(T_a, T_w)$ be the maximum innovation cost that can be covered by the worldwide intellectual property rights (T_a, T_w), namely

$$\hat{c}(T_a, T_w) = v^a \pi T_a + v^w \pi T_w \qquad (11.1)$$

When country a increases the length of protection T_a, it increases the number of innovations at the margin, because innovations with cost just

greater than $\hat{c}(T_a, T_w)$ will now be forthcoming. The increase in innovations comes not only from country a, but also from country w.

As before, assume that each innovation has the same market in each country, described by v^a, v^w, but that innovations may have di®erent costs, c. Assume that the costs c of potential innovations in country a are distributed according to a function F such that there are $F(c)$ potential innovations with cost less than or equal to c. Thus, if the highest cost that can be covered with intellectual property is $\hat{c}(T_a, T_w)$, there will be $F(\hat{c}(T_a, T_w))$ innovations in country a. Assume that the costs of potential innovations in country w are distributed the same way, but scaled by a parameter γ. If the highest cost that can be covered with intellectual property is c, there will be $\gamma F(c)$ innovations in country w. Thus country w is more or less innovative than a according to whether $\gamma > 1$ or $\gamma < 1$. With policies (T_a, T_w) in place, there will be $(1 + \gamma)F(\hat{c}(T_a, T_w))$ innovations in countries a and w { that is, all the innovations with $c \cdot \hat{c}(T_a, T_w) = \pi(v^a T_a + v^w T_w)$ will be undertaken in both countries.

It is also useful to have notation for the total costs of innovation in the countries, as well for the total numbers of inventions. With policies (T_a, T_w) in place, the cost of the marginal innovation is $\hat{c}(T_a, T_w)$. However, the total cost includes inframarginal innovations as well. Let $Y(c)$ be the total cost of all potential innovations in country a with cost less than or equal to c.[5] This total cost will satisfy $Y(c) < cF(c)$ for each c, since there are $F(c)$ such innovations, and all except the marginal one have cost less than c. Similarly, the cost of all potential innovations in w with cost less than c is $\gamma Y(c)$.

Let $S(\cdot)$ represent aggregate social welfare as a function of (T_a, T_w):

$$S(T_a, T_w) = (1 + \gamma)F(\hat{c}) \sum_{i=a,w} v^i \left(\frac{1}{r} - \ell T_i \right) - (1 + \gamma)Y(\hat{c})$$

where $\hat{c}$ is given by (11.1).

The ¯rst term is the discounted consumers' surplus generated by innovations in both countries. There are $(1 + \gamma)F(\hat{c})$ such innovations, since innovators develop all potential innovations with cost less than $\hat{c}(T_a, T_w)$.

[5] Suppose that the cumulative distribution of costs F has density f. Then the number of innovations with cost less than $\hat{c}$ is $F(\hat{c}) = \int_0^{\hat{c}} f(z)dz$, and those innovations have total cost $Y(\hat{c}) = \int_0^{\hat{c}} zf(z)dz < \hat{c} \int_0^{\hat{c}} f(z)dz = \hat{c}F(\hat{c})$.

Regardless of which country created the innovation, it provides consumers' surplus and profit in both countries, for a total of $\sum_{i=a,w} v^i((1/r) - \ell T_i)$. On any innovation, the total consumers' surplus plus profit in country a is $v^a((1/r) - \ell T_a)$, namely, the discounted consumers' surplus under competitive supply, $v^a(1/r)$, minus deadweight loss during the patent life, $v^a \ell T_a$.[6] Symmetrically, the total consumers' surplus plus profit in country w is $v^w((1/r) - \ell T_w)$. The last term of $S(\cdot)$ represents the total cost of innovation in both countries.

However, neither country will choose its policy to maximize the total social welfare $S(\cdot)$. To characterize the choices of the two countries, focus on country a. The choice of country w can be described symmetrically, by reversing a and w and recognizing that the number of innovations and cost in w are γ times those in a. Region a's objective function is W^a:

$$\begin{aligned} W^a(T_a, T_w) \;=\; & F(\hat{c})\, v^a \left[\frac{1}{r} - \ell T_a\right] + \gamma F(\hat{c})\, v^a \left[\frac{1}{r} - (\ell + \pi) T_a\right] \\ & + F(\hat{c})\, v^w \pi T_w - Y(\hat{c}) \end{aligned} \tag{11.2}$$

where $\hat{c}$ is again given by (11.1). The first term is the consumer and producer benefits in country a that accrue from innovations in a. The second term is the consumer benefits in country a that accrue from innovations in w. The third term is the profit that country a can collect from country w. The fourth term is the cost of country a's innovations.

The benefits of foreign innovations (the second term of (11.2)) do not include profit, which flows out of country a to country w. However, the third term represents the reverse profit flow, from w to a, due to intellectual property rights that domestic innovators in country a are granted in w.

Suppose now that country a contemplates an increase in its length of protection T_a. What are the benefits for the world as a whole, and what are the benefits for country a? First, there will be more innovations in both countries, due to national treatment. When T_a is larger, the cost $\hat{c}(T_a, T_w)$ of the marginal innovation is larger, so there are more innovations. In the social welfare function $S(\cdot)$, there are more total innovations, since $(1 + \gamma)F(\hat{c})$ goes up, and these innovations create benefits for consumers in both a and w.

[6] Notice that $c^a((1/r) - \ell T_a)$ is equal to $c^a((1/r) - T_a) + c^a m T_a + c^a \pi T_a$, since $\ell = 1 - m - \pi$. The first term is the consumers' surplus that accrues after the patent expires. The second term is the consumers' surplus at the proprietary price while the intellectual property is protected, and the third term is the profit.

However, country a cares only about the bene¯ts and costs that accrue domestically. It vastly undervalues the global bene¯ts by not taking account of the bene¯ts that accrue to consumers and innovators in country w. In fact, the additional pro¯ts that accrue to innovators in w weigh directly against country a's domestic interests, since the pro¯ts are paid partly by country a's consumers. The increased out°ow of pro¯t is not only on the marginal innovations with cost $c(T_a, T_w)$ that are brought about by the longer protection, but also on the many innovations with lower cost $c < c(T_a, T_w)$ that would be undertaken even with shorter protection. The increase in T^a generates an out°ow of pro¯t to country w on all of its innovations, not only the incremental ones that arise from the increase in T_a.

This argument holds not only for country a, but symmetrically for country w. Neither country will have an incentive to support as much innovation as required to maximize aggregate global welfare $S(¢)$. This is due to pro¯t °ows and because domestic policymakers do not value the bene¯ts created for foreigners. It is important to notice that this result holds even if the countries are completely symmetric, so that the externalities conferred across borders balance out. That is, it holds even if the innovativeness is the same (γ = 1), the markets are the same (v^a = v^w), and the countries start from the same levels of protection T_a = T_w.

This demonstrates a misfortune of equilibrium that arises in many economic contexts. If one actor is choosing the socially best policy, the other actor can often exploit that fact by deviating from its own socially best policy in a way that serves its own interests at the expense of the other. Consequently an equilibrium can be worse for both parties than some other outcome they would like to agree on. The best intellectual property policy consists of the $(T_a^¤, T_w^¤)$ that maximizes $S(¢)$. But starting from an optimum $(T_a^¤, T_w^¤)$, each country, assuming the other country's policy will stay ¯xed, has an incentive to shorten its protection.

Can this problem be ¯xed? One of the main achievements of the TRIPS agreement was to set minimum lengths of protections, twenty years in the case of patents. Let $T^¤$ be a value such that $S(T^¤, T^¤)$ ¸ $S(T, T)$ for all T { that is, a common patent life that cannot be improved on for the world as a whole. If the countries sign a treaty to protect for $T^¤$ years, then neither can shorten its protection even though it would like to. By committing themselves in this way, they are better o® than if they were free to change their policies.

When the countries are symmetric, the harmonization problem is easy,

because the countries agree on the optimum. Their pro¯t °ows are o®setting and their innovations confer equal and reciprocal bene¯ts. A policy that is good for one is also good for the other. However, when the countries are di®erent in size or innovativeness, they may not agree. Even if the lengths of protection $(T_a^{\ddagger}, T_w^{\ddagger})$ maximize $S(\cdot)$, the social bene¯ts will not fall on the two countries equally. Cross-border pro¯t °ows and cross-border spillovers are asymmetric.

Suppose, for example, that country a has a larger market than country w, $v^a > v^w$, but that they have the same innovative capacity, $\gamma = 1$. Would we expect country a to favor longer or shorter harmonized protection T than country w favors?

Notice that this experiment is di®erent from asking, as we did above, what level of protection each country would choose if it could choose its protection independently of the other country. Here, the countries must come to an agreement. Instead of characterizing what each country will \choose" (since the choice is not entirely under its own control), we will characterize what each country would \advocate", if it believed it could win the negotiation so that both countries implemented its preference. We show that country a prefers a longer harmonized protection than country w when

- The countries are equally innovative but country a has a smaller market.
- The countries have the same-size markets, but country a is more innovative.

When country a contemplates the common level of protection T that would be best for its own domestic interests, it is asking what level of T maximizes $W^a(T, T)$. Similarly, country w is asking what level of T maximizes $W^w(T, T)$. By inspecting (11.2) and imposing a harmonized outcome, $T_a = T_w = T$, we see that an increase in T has two e®ects. First, there is a direct e®ect of increasing the deadweight loss on domestic consumers consuming both foreign and domestic innovations. The deadweight loss imposed on domestic consumers in country a is $v^a \ell T F(\hat{e})(1 + \gamma)$, and in country w is $v^w \ell T F(\hat{e})(1 + \gamma)$. Deadweight loss is smaller in a smaller region { that is, smaller in region a if $v^a < v^w$. This feeds the ¯rst bullet point.

Second, an increase in the harmonized length of protection, T, will change the net °ow of pro¯t to country a, namely, $F(\hat{e})\, v^w \pi T - \gamma F(\hat{e})\, v^a \pi T$,

which can be either negative or positive. The net °ows in the two countries sum to zero, so that one country gains pro¯t, and the other loses pro¯t. If the countries are equally innovative ($\gamma = 1$), then an increase in T will increase the net °ow of pro¯t to country a if and only if country a is smaller than w. This is again the ¯rst bullet point above. But if the sizes of markets are the same ($v^a = v^w$), then an increase in T will increase the net °ow of pro¯t to country a if and only if it is more innovative than country w { that is, $\gamma < 1$. This shows the second bullet point above.

Thus, harmonization will not resolve all disagreements. The countries will disagree on the best harmonized protection in a way that still re°ects asymmetric externalities.

We conclude this section by comparing the countries' preferences about harmonization to the T^{α} that maximizes $S(\phi)$. Recall that if the countries make independent choices, they will choose protections that are too short. Does this de¯ciency remain when they negotiate to harmonize?

In fact, we have already sorted this out. In the symmetric case, the countries will agree to harmonize on the e±cient level of protection that maximizes $S(\phi)$. Otherwise, the smaller or more innovative country prefers longer-than-optimal protection, while the larger country prefers shorter-than-optimal protection.

In the TRIPS negotiation, the rich industrialized nations such as the United States pushed hard for strengthening intellectual property rights. The rich industrialized nations have both high innovative capacity and large markets. The preceding arguments suggest that it is the innovative capacity, not the size of the market, that caused the large developed countries to be strong advocates of intellectual property. The size of the market cuts the other way. Based on the foregoing arguments, small, very innovative countries should be most enthusiastic about strengthening global intellectual property rights. Switzerland, for example, was a strong advocate.

11.4. National Autonomy and Protected Subject Matters

Although the TRIPS agreement sets minimum lengths of protection and mandates the protection of many types of knowledge, it also leaves scope for national autonomy. For example, although TRIPS requires protection for computer software, it does not require United States-style patents for

software or that business methods be protected.

Since nations can exercise autonomy in protecting certain subject matters, choosing subject matters is another way to escape the common lengths of protection. Region a can e®ectively choose $T_a = 0$ by not protecting the subject matter at all. When will it have an incentive to do this? What will a subject-matter harmonization look like?[7]

We can ask the same questions about protected subject matter as we asked for length of protection: If nations choose independently which subject matter to protect, as they did prior to TRIPS, will they protect too much or too little? How will the externalities °ow? What will a harmonization e®ort lead to?

We will answer this question within the framework of a harmonized length of protection. All subject matter protected by patents is protected for twenty years, and similarly for other general-purpose protections like copyright. Within this framework, the problem raised by independent choices is again free riding. The fear of free riding is illustrated by what happened when the United States computer chip manufacturers lobbied Congress for some form of chip protection in the early 1980s. United States chip developers such as Intel had failed to get the courts to recognize copyright protection for their semiconductor chips and were uncertain whether patents would be granted. They therefore lobbied Congress for a special act, which became the Semiconductor Chip Protection Act (SCPA) of 1984, to grant them protection against copying (\cloning") of chips. Cloning has been automated and is very cheap compared to the cost of designing a new chip. The potential competition therefore threatened the viability of chip development.

However, protection in the domestic American market would not protect American chip developers from foreign manufacturers who could clone United States chips and market the clones abroad. With national treatment, foreign jurisdictions would be in the best of all possible worlds, receiving protection for their own innovators in the large American market, but having a competitive supply of chips in their own markets.

Congress addressed this threat by including a reciprocity requirement in SCPA. Protection was denied to any chip developer whose home jurisdiction did not provide reciprocal protection for American chip makers. Even though SCPA was not part of the patent and copyright systems covered

[7] For a more elaborated version of this discussion see Scotchmer, 2004.

by the Paris and Berne Conventions, the reciprocity provision was controversial because it °outed the well-established principle of national treatment. (In 1996, the European Union retaliated in a directive calling on the member states to enact sui generis protection for databases. They included a provision that database providers domiciled in nonmember jurisdictions like the United States would not be protected unless the nonmember jurisdictions provided similar database protection.)

For subject matters protected by patent or copyright, it is not possible under the Paris and Berne Conventions to provide stronger protection than required by TRIPS unless it is provided symmetrically to both domestic and foreign inventors. As illustrated by this example, that puts jurisdictions in a bind. On the one hand, inventors may need protection to cover their costs, but on the other hand, no jurisdiction wants to provide that protection unilaterally. If any jurisdiction provides it unilaterally, then the other jurisdictions have an incentive to free ride.

We now make these arguments more formally. Assume, as before, that each innovation has a market size v^a in country a and v^w in country w. The harmonized length of intellectual property protection is T. We will now group subject matters in terms of the cost c: some are cheap to develop, and others are expensive. For simplicity, assume that $v^a < v^w$ (the indices a and w can be reversed to consider the other case), and consider four types of subject matter, de¯ned by the following conditions on their cost c:

Case I	$c \cdot \pi v^a T < \pi v^w T$
Case II	$\pi v^a T < c \cdot \pi v^w T$
Case III	$\pi v^a T < \pi v^w T < c \cdot \pi T (v^a + v^w)$
Case IV	$\pi T (v^a + v^w) < c$

In case I, protection in either jurisdiction is su±cient to cover cost. With independent choices, there are two equilibria: one in which the subject matter is protected in the smaller market, a, as is e±cient, and the other in which the subject matter is protected in w, which generates more deadweight loss.

In case II, the only equilibrium is where the subject matter is protected in w, and that is e±cient.

In case III, there are two equilibria. In one equilibrium, the subject matter is protected in neither country. Conditional on seeing that there is no

protection in w, there is no reason for country a to provide protection, since protection would be ine®ective, and vice versa. In the other equilibrium, the subject matter is protected in both countries.

In case IV, protection would be ine®ective even if bilateral.

Case III illustrates a coordination problem that can arise. If bilateral protection is required to cover costs, then independent choices may lead to no protection at all. Conditional on country w not protecting the subject matter, country a sees no reason to protect it because unilateral protection would be ine®ective in any case. Harmonization can ¯x this coordination problem. If the countries sit down at a bargaining table, they will presumably agree that bilateral protection is better than none.

Harmonization can also ¯x the equity problem that arises when the outcome would be protection in a single market, as in cases I and II. Of course, the free riding jurisdiction will oppose this harmonization. Fixing the equity problem with harmonized bilateral protection is a second-best solution, since it leads to high prices in both jurisdictions and deadweight loss. Two other solutions would be to (1) relax the principle of national treatment and allow each jurisdiction to protect only its own inventors (the countries would then confer externalities symmetrically on each other); (2) allow di®erent subject matters to be protected for lengths of time that re°ect their costs. (For low-cost subject matters, the length of protection would be shortened so that the relevant inequality would be the third one instead of the ¯rst or second, and then bilateral protection would be no less e±cient than unilateral protection.)

Neither solution is likely to be proposed. National treatment is solidly entrenched. And tailoring length to cost is essentially impossible on a case-by-case basis, since cost is impossible to verify (see chapter 2). It might be possible to cleave o® certain subject matters that are known to be particularly low cost on average, but that would require sui generis forms of protection, rather than the one-size-¯ts-all regimes of patent and copyright.

11.5. Intellectual Property and the Public Domain

The foregoing arguments assume that, absent an e®ective intellectual property regime, innovation will not take place. That supposition ignores the large role played by the public sector in R&D spending. As pointed out in

chapter 8, public spending accounts for between one-quarter and one-half of R&D spending almost everywhere in the industrialized world, and mostly closer to half. We now consider how the preceding arguments must be modi¯ed if an alternative to e®ective intellectual property protection is public sponsorship rather than a dearth of innovation.

As stressed in chapter 2, public sponsorship has a natural advantage over intellectual property incentives. Public sponsors can fund R&D out of general revenue and then put the resulting knowledge in the public domain, thus reducing deadweight loss. If we think that intellectual property is a better incentive system, it is either because we value the fact that everyone who helps pay for the innovation does so voluntarily, or because public sponsorship introduces some kind of ine±ciency that is worse than deadweight loss.

In the international arena, private incentives can have another advantage for regional taxpayers. Public sponsors are unlikely to marshal public funds for R&D investments whose bene¯ts lie largely outside their own borders. In contrast, intellectual property rights abroad can allow investors to reclaim some of this external bene¯t as pro¯t. As a consequence, public sponsors may not support innovations that the private sector would support, even if the public sector is much more e±cient in avoiding deadweight loss.

If an innovation is in the public domain, the per-period bene¯t that it confers in country a is v^a. It is reasonable to suppose that a public sponsor will only fund a project for the public domain if it generates domestic bene¯ts $(1/r)v^a$ that are greater than the cost. It also generates bene¯ts $(1/r)v^w$ abroad, but these are of no concern to policymakers in a. If the innovation is protected in both countries, the pro¯t is $\pi\,(v^aT_a\ +\ v^wT_w\ )$. It can easily happen that for some innovation with cost c, $(v^aT_a\ +\ v^wT_w\ )\pi > c > (1/r)v^a$. Even though the cost of the invention is greater than $(1/r)v^a$, so that a public sponsor would not undertake the investment, the investment would be undertaken by a private investor to collect pro¯t.

For innovations likely to be supported by the public, the possibility of public sponsorship will change our notion of which subject matters should be protected by intellectual property. If inventions will be publicly sponsored rather than lost in the absence of protection, the argument for intellectual property is weaker. However, even within this modi¯ed framework, the previous results hold. It is still true that the countries will choose too little protection if they choose independently, will strengthen protections if they

have an opportunity to harmonize, and will generally disagree. One country will favor protection that is too strong, and the other will favor protection that is too weak (Scotchmer 2004).

In keeping with a common view of the public sector, assume that publicly sponsored research is more costly than private research. Thus, if the private cost of a development effort is c, the public cost is kc, $k > 1$. We now interpret F as describing the distribution of costs within a given subject matter.

The following questions arise: (1) When is intellectual property more efficient than public sponsorship in the sense that global deadweight loss is less than the cost disadvantage of the public sector? (2) Will independent choices of subject matter coincide with what is efficient? (3) What is the likely outcome of a harmonization effort?

It is useful to write down the conditions under which country a would prefer to protect the subject matter, assuming that otherwise public sponsors would step in. Conditions (11.3) and (11.4) are useful in understanding what happens with independent choices, and (11.5) is useful in understanding the countries' incentives to harmonize. Again let $\hat{c}(T,T)$ defined by (11.1) represent the maximum R&D cost that could be covered by the profit available in both markets, where T is the harmonized length of protection. The three conditions that follow apply under three different assumptions about country w's policy.

Assuming that country w does not protect a subject matter, country a will protect it if

$$v^a \ell T \ (1+\gamma) F(v^a \pi T) + v^a \pi T \ \gamma F(v^a \pi T) < (k-1) Y(v^a \pi T) \qquad (11.3)$$

Assuming that country w protects the subject matter, country a will protect it if

$$v^a \ell T \ (1+\gamma) F(\hat{c}) + v^a \pi T \ \gamma F(\hat{c}) - v^w \pi T \ F(\hat{c}) + v^w \pi T \ F(v^w \pi T) \qquad (11.4)$$

$$< (k-1)\left(Y(\hat{c}) - Y(v^w \pi T)\right)$$

Finally, assuming that the choice is between harmonized bilateral

protection for (given) length T and no protection in either country, country a will favor bilateral protection of the subject matter if:

$$v^a \ell T \ (1 + \gamma) \, F(\hat{e}) + v^a \pi T \, \gamma F(\hat{e}) - v^w \pi T \, F(\hat{e}) < (k - 1) Y(\hat{e}) \qquad (11.5)$$

In each inequality, the right-hand side is the saving in R&D costs that would result from protection of the subject matter in country a instead of public sponsorship, and the left-hand side is the deadweight loss and net loss in profit. If the cost saving outweighs the deadweight loss and net outflow of profit, so the inequality holds, the country will protect the subject matter.

The inequalities (11.4) and (11.5) can hold even if $k = 1$, so that the private sector has no cost advantage over the public sector. In a purely domestic context, the case of $k = 1$ would be a clear case for public sponsorship, since public sponsorship avoids deadweight loss. But in the international context, profit flows can make intellectual property an attractive domestic policy despite the deadweight loss.

The most important observation, arising directly from a comparison of (11.4) with (11.5), is that a harmonization effort is likely to restrict the public domain relative to what would happen with independent choices. Whenever (11.4) is satisfied, (11.5) is also satisfied, but not vice versa. This implies that the countries will advocate stronger protections (more protected subject matter) if they know they will get reciprocity than if they must make independent decisions. Countries will agree to harmonized protections that either country would drop if given the right to do that.

Consider what country a gains by dropping the subject matter unilaterally. With a unilateral defection, country a stems the flow of profit to inventors in country w. A bilateral reduction in protection would also deprive country a of the profit it earns in country w, and this is the difference. If both must happen simultaneously, country a will be more keen to keep the protection.

Of course these arguments do not reveal whether protection of the subject matter is globally efficient or inefficient, but only that independent choices are more likely to leave inventions in the public domain. The condition under which bilateral protection is efficient, in the sense of

minimizing global deadweight loss net of R&D costs, is

$$\ell T \left[\sum_{i=a,w} v^i \right] (1+\gamma) F(\hat{e}) \cdot (k - 1)(1+\gamma) Y(\hat{e}) \tag{11.6}$$

Unlike (11.3) through (11.5), this comparison of deadweight loss to cost ine±ciency does not contain pro¯t °ows.

To compare the e±cient outcome with independent choices, take the marginal case, where (11.6) holds with equality. Then, with independent choices, at most one country will protect the subject matter, and it is possible that neither will. For example, in the symmetric case ($v^a = v^w$ and $\gamma = 1$), if (11.6) holds with equality, then neither (11.3) nor (11.4) holds, so that the equilibrium with independent choices will be that neither country protects the subject matter, even though protection would be e±cient.

Now consider harmonization. If we add the inequality (11.5) and its mirror image for country w, switching the superscripts a and w, and recognizing that the number of innovations and cost in w are γ times those in a, the inequality (11.6) is precisely what we get. It follows that, if (11.6) holds with equality, then either (11.5) holds or its mirror image for w holds. One country will favor harmonized bilateral protection and the other will oppose it, except in the perfectly symmetric case where they agree. Although the countries generally disagree, their preferences bracket what would be e±cient. We can also see from (11.5) that the disagreement will take the following form:

- If the countries have the same market size, but country w is more innovative than country a, in the sense that $\gamma > 1$, then country w will favor bilateral protection of the subject matter whenever country a favors it, but not vice versa.
- If the countries are equally innovative ($\gamma = 1$), but country w has a smaller market than country a ($v^a > v^w$), then country w will favor bilateral protection of the subject matter whenever country a favors it, but not vice versa.

11.6. National Autonomy and Trade Rules

When the intellectual property covers a good sold in the market, as discussed in the previous three subsections, any unauthorized use is an infringement and can be stopped. Unauthorized imports (\parallel imports") can be stopped at the border. As a consequence, intellectual property can be protected in some but not all countries. There is a large measure of national autonomy in protections, at least where TRIPS is silent.

This is not necessarily true of intellectual property that protects inventions other than consumer goods. Di®erences in national rules can sometimes be arbitraged so that national autonomy is undermined (Samuelson 2004). Several examples follow.

The ¯rst example concerns research tools. A research tool is knowledge, perhaps in the form of an instrument or chemical structure, that aids a researcher in developing further knowledge, but it is not typically embodied in the further product once it is developed or in the process of manufacturing the product. In biotechnology, the research tool may be a technique for combining genetic material in bacteria that will then produce useful proteins. Once the bacterium exists, the research tool is no longer required, and there is no evidence in the bacteria that it was used. In computer programming, the research or development tool may be an automated way to generate boilerplate code that is required for routine operations. Once the code exists, there may be no evidence that it was developed with the tool.

Research tools are problematic for several reasons, even in the domestic arena. One is philosophical. Research tools may be examples of knowledge in which investment is mostly uncontroversial, and for which the bene¯ts are widespread. Using the arguments in chapter 2, they are therefore good candidates to be publicly sponsored and put in the public domain.

Another problem has to do with enforcement. Even in the domestic arena, it is di±cult to verify that a protein-producing bacterium was developed with the unauthorized use of a research tool. If infringements cannot be detected, the intellectual property cannot be enforced.

The enforcement problem is compounded in the international arena by ambiguities in trade rules that keep derived products out. Trade rules treat the importation of proprietary products, and products produced with

proprietary processes, di®erently than products developed with proprietary research tools. In the case of products, provenance does not matter, since unauthorized sale or use is an infringement. Prior to the Process Patent Amendments Act of 1988, which added section 271(g) to the Patent Act, there was no law prohibiting the importation of products made abroad with infringing processes. That was an untenable situation, since it created incentives to manufacture products o®shore, to avoid paying royalties when the products were imported. Section 271(g) remedied that problem for process patents but makes no mention of research tools. Since the research tool is not required to manufacture the product { development and manufacture are di®erent things { there is no presumption that 271(g) applies.

If there are jurisdictions where a particular research tool is not protected, use of the research tool may be pushed o®shore. Adding insult to injury, products developed with the research tool could then, absent clear and enforceable trade rules, be proprietary in all jurisdictions where such products are protected, without obliging the seller to pay royalties to the developer of the research tool. In the extreme case, this would deprive the research tool of its commercial value even in the country where it was invented, a situation that is hard to distinguish from not having protection at all.

The second example concerns e®orts to enable price discrimination. As chapter 2 pointed out, price discrimination can serve the interests of both consumers and producers. The di±culty of price discrimination is in ¯nding the submarkets where customers with similar willingness to pay are clustered, and preventing resale from low-priced market segments to high-priced segments.

In the international arena, the market is segmented automatically to the extent that willingness to pay is determined by culture and income. The movie industry has developed a clever means of exploiting this segmentation by coding DVD players and DVD movies with country codes. A movie can only be played on a DVD player if the country code matches. This prevents movies priced for the Asian market from being resold to play on American machines.

Country codes are a form of encryption, and they can be circumvented. In the United States, such circumvention is illegal under the DMCA (see chapter 7). However, its legality elsewhere is still being debated. If it is not illegal to reverse engineer the country code in, say, Finland, clever

technologists can undermine the content providers' attempt at price discrimination by doing so, and then arbitrage the low-priced and high-priced markets. This will put upward pressure on price in markets where the content providers would otherwise charge a lower price.

These international arbitrage opportunities have the consequence that intellectual property protections are automatically harmonized, usually toward the least protective regime. National autonomy will be hard to preserve in any meaningful way.

11.7. Externalities and International Cooperation

Since the public has no means to recoup cross-border external bene¯ts that arise from innovations that it puts in the public domain, the large amount of public research is perhaps surprising. Large public research programs are mainly undertaken by large industrialized countries competing, among other things, for prestige. Still, prestige may be a thin thread on which to hang the justi¯cation for a public R&D program.

A natural way to overcome externalities is joint funding. In fact, there are several impressive examples, mostly involving big science, where blocks of countries have coordinated their research spending for mutual bene¯t. Several European countries collaborated on a particle accelerator called CERN, located in Switzerland, which is an important nuclear research facility for European physicists and is also used by Americans. Another such research facility is the International Space Station, which is mostly funded by the United States, but also has major contributions from Russia and other countries. Finally, the Canada-France-Hawaii telescope, located in Hawaii, shows how international coooperation extends to even relatively small-scale facilities.

Cooperation can also occur implicitly and without common facilities. Since 1945, governments have understood that current fossil-fuel and nuclear-energy technologies cannot meet society's demand for electricity inde¯nitely. By contrast, a successful fusion technology would generate essentially limitless energy from an isotope, deuterium, found in seawater. Governments in the United States, Europe, Russia, and Japan have all invested heavily to solve this problem. Interestingly, di®erent countries tend to pursue di®erent technical strategies (see Maurer and Scotchmer 2004). This has presumably limited duplication and facilitated an aggregate

investment that no single country could a®ord.

Despite these successes of international cooperation, the area of cooperation with perhaps the highest payo®, pharmaceuticals, remains ¯rmly in private hands.

11.8. Conclusion

The notion of an optimal incentive strucuture must be reinterpreted for the international context. In a domestic context it is natural to de¯ne an optimal incentive mechanism as one that maximizes the sum of bene¯ts that accrue to consumers and innovators, recognizing that innovators must receive bene¯ts in order to discover new knowledge. In the international arena, domestic policymaking is in°uenced by pro¯t °ows. Stronger protection at home increases the pro¯t °ow to foreigners, and stronger protection abroad bolsters the pro¯t °ow to domestic innovators.

From an overall global point of view, pro¯t °ows are merely transfers, but they nevertheless have an important impact on domestic policymaking. No country's domestic calculation of an optimal policy will accord with the policy that is optimal from the point of view of maximizing the sum of global bene¯ts. We concluded that, when countries must provide national treatment to foreign inventors but make independent choices about the length of protection or the subject matters covered, their domestic interests are best served by choosing protections that are shorter or cover fewer subject matters than would be optimal from a global perspective. This is directly because of the pro¯t °ows. Harmonization will generally strengthen protection.

Pro¯t °ows are a®ected by the relative sizes of domestic markets and by the relative sizes of the countries' innovative capacities. We showed that the countries' bargaining positions in the international negotations over harmonization will likely re°ect these two aspects. Countries with smaller markets should favor stronger protections, as should countries with more innovative capacity. This seems to have been broadly true in the TRIPS negotiation.

Much of this book has been concerned with the proper balance between public funding of R&D and sponsorship by the private sector under a system of intellectual property rights. The international arena tilts the balance toward privatization, because intellectual property protection allows

some spillovers to be repatriated to the innovating country. It is hard to see why domestic public sponsors would devote public funds to a project unless domestic bene¯ts outweigh the costs. However, there are many worthy projects for which worldwide bene¯ts outweigh the costs, even if domestic bene¯ts do not, especially in a small country. Intellectual property incentives can often overcome this problem. Under a system of reciprocal national treatment, foreign users of a protected innovation will be taxed through proprietary pricing, so that some of the bene¯ts conferred abroad can partially be repatriated.

If, as this line of reasoning suggests, worldwide innovation policies have shifted ine±ciently away from public sponsorship and toward the private sector, then the cuprit probably lies in a dearth of international e®orts to coordinate and commit to public spending on R&D. There are no international organizations for public spending that are analogous to the TRIPS negotation for intellectual property rights.

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